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A PRELIMINARY REPORT ON THE FIRST YEAR'S FFECTS OF TIMBER HARVESTING ON WATER YIELD FROM A COLORADO WATERSHED

by

Bertram C. Goodell

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ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION
Raymond Price, Director Fort Collins, Colorado

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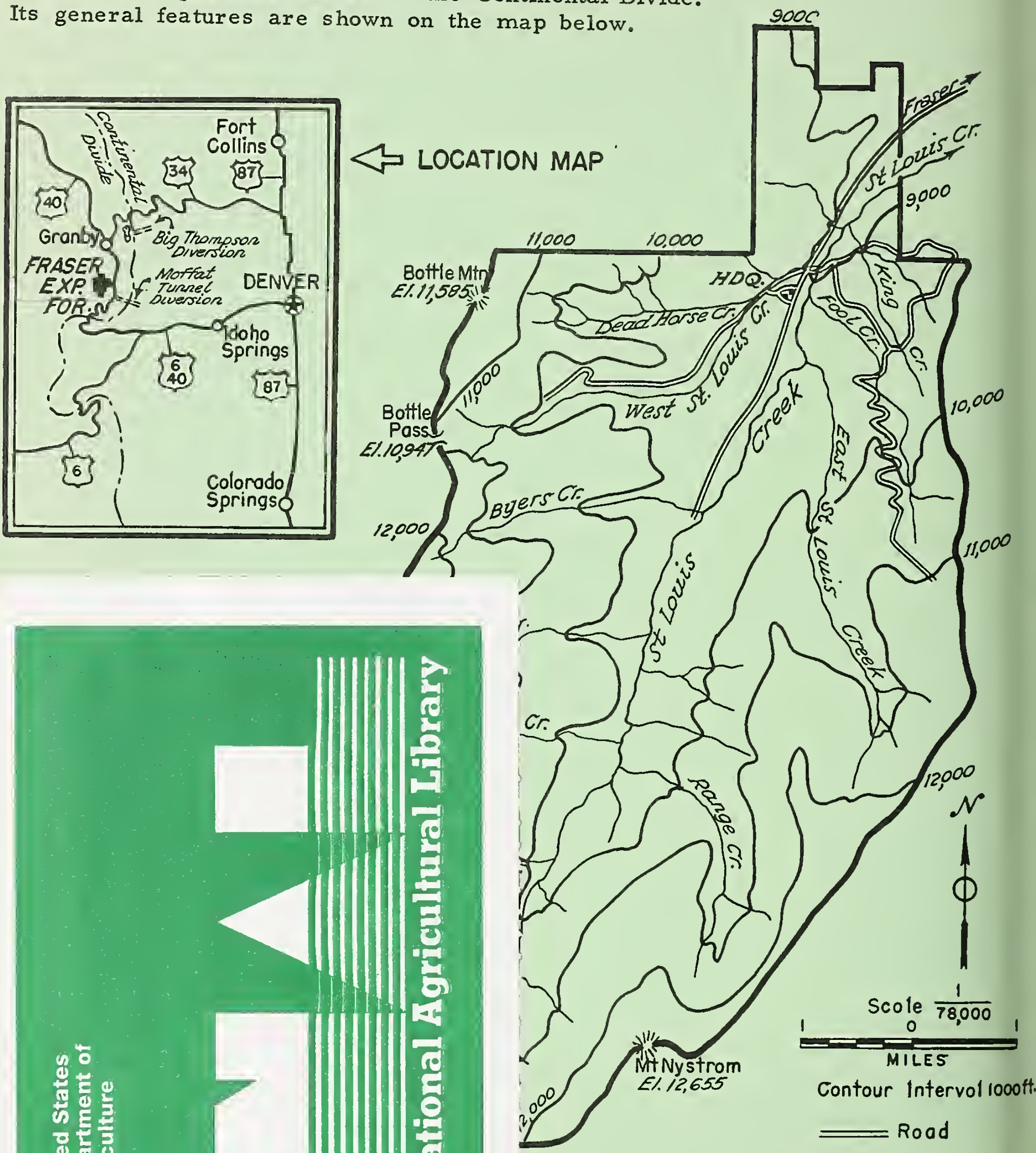
FRASER EXPERIMENTAL FOREST

LOCATION

The Fraser Experimental Forest lies 65 miles west and north of Denver. The experimental area totals 36 square miles, and represents the land of the Continental Divide. Its general features are shown on the map below.



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by

Bertram C. Goodell, Forester

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The station maintains central headquarters at Fort Collins, Colorado, in cooperation with Colorado State University.

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INTRODUCTION

A progress report of the watershed experiments at the Fraser Experimental Forest near Fraser, Colorado, is made at this time because of widespread public interest in the experiments. The report summarizes 12 years of streamflow records before the harvesting of timber and only 1 year after the completion of timber cutting. Consequently, the effects described here are of a preliminary nature only, and are not necessarily indicative of what might be expected over a period of several years.

The Fool Creek watershed originally supported a mature to overmature stand of lodgepole pine (Pinus contorta Dougl.), Engelmann spruce (Picea engelmannii Parry), and subalpine fir (Abies lasiocarpa (Hook.) Nutt.). Merchantable forest covered 550 acres of the total 714 acres in the watershed, with 55 percent occurring in the lodgepole pine type and 45 percent in the spruce-fir type. The stand was estimated to be 250 to 300 years old. Lodgepole pine predominated on the slopes at lower elevations and on the exposed ridges of upper elevations, while spruce and fir dominated the stream courses and the more moist, protected sites at higher elevations. On the 550 acres, the sawtimber volume (10 inches d.b.h. and larger) averaged 12,000 board-feet per acre. The 164 acres containing no merchantable timber lies near timberline and supports an open, scrubby growth of spruce and fir that had been partially burned nearly 100 years ago.

The elevational range of the watershed is from 9,600 to 11,500 feet. The primary direction of the stream is from south to north, and slopes face west, north, and east. Slope gradients vary from 10 to 60 percent, with an average of about 25 percent. The soils are derived from gneiss and schist and are coarse in texture. The depth of weathered material averages 8 feet or more.

Precipitation averages about 30 inches annually, of which three-fourths falls as snow during October to June. Summer rains are frequent but of low intensity or very brief. These precipitation characteristics, together with the nature of the soil, tend to prevent erosion.

From October through early April the snow accumulates without melting, and the discharge of Fool Creek, maintained by deeply stored ground water, drops gradually but constantly. The spring freshet starts between mid-April and mid-May, and reaches its peak sometime in June. After this annual peak, the rate of streamflow declines steadily, except after occasional summer rains, until the start of snowmelt the following spring.

Research on Fool Creek was begun in 1943 with the completion of stream gages there and on a nearby stream, East St. Louis Creek (cover photo). The drainage area of East St. Louis Creek is 1,984 acres. Records of the discharge by each stream from 1943 to 1954 provided the basis for a regression equation by which the discharge of Fool Creek can be accurately predicted from the recorded discharge of East St. Louis Creek.

Preparation to harvest timber from the Fool Creek watershed was begun in 1950 and 1951, with the construction of 11.9 miles of logging road: 3.3 miles are main access road and 8.6 miles are spur roads. The road network and cutting pattern are shown in figure 1.

The harvesting of timber was initiated in early summer of 1954 and completed in the fall of 1956. The pattern of cutting consists of alternate clear-cut strips running across the contours and bounded at the ends by the contour roads. Four widths of strip were used: 1, 2, 3, and 6 chains. The area of merchantable timber was divided into 4 equal blocks and the 4 strip widths were repeated on each block. The slope length of most strips is approximately 600 feet, the slope distance between spur roads. Horse skidding and some uphill cable skidding were used to move logs to the roads. To minimize damage to the stream course, no timber was cut within 90 feet of the main stream.

On the strips designated for cutting, all live trees 4 inches d.b.h. and larger were felled. The tops were lopped and scattered. The pine was converted into poles, sawlogs, and posts; the spruce and fir, into sawlogs and pulpwood. The appearance of a typical cleared strip is shown in figure 2.

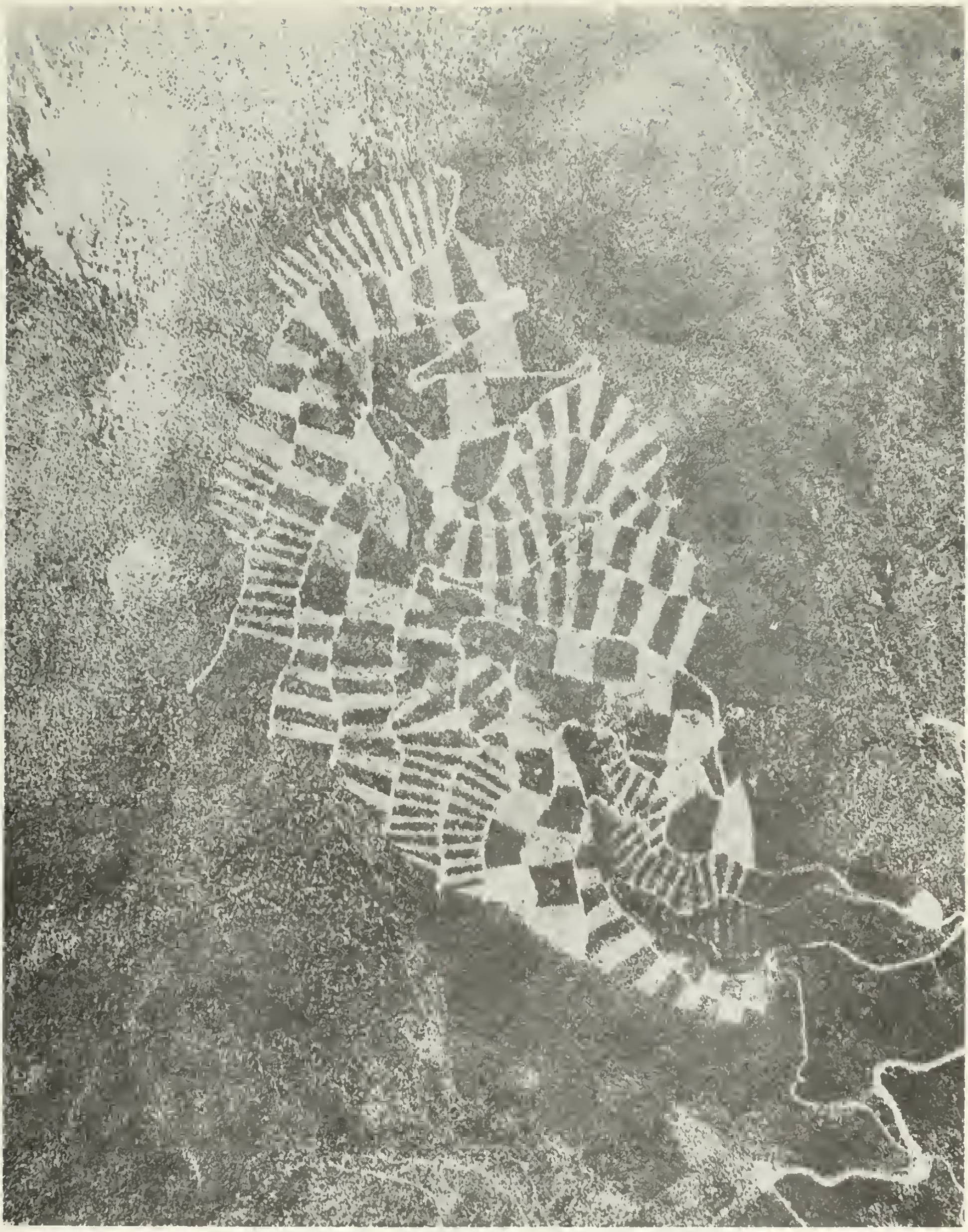

Figure 1. --Aerial view of Fool Creek watershed showing road network and pattern of timber harvest.

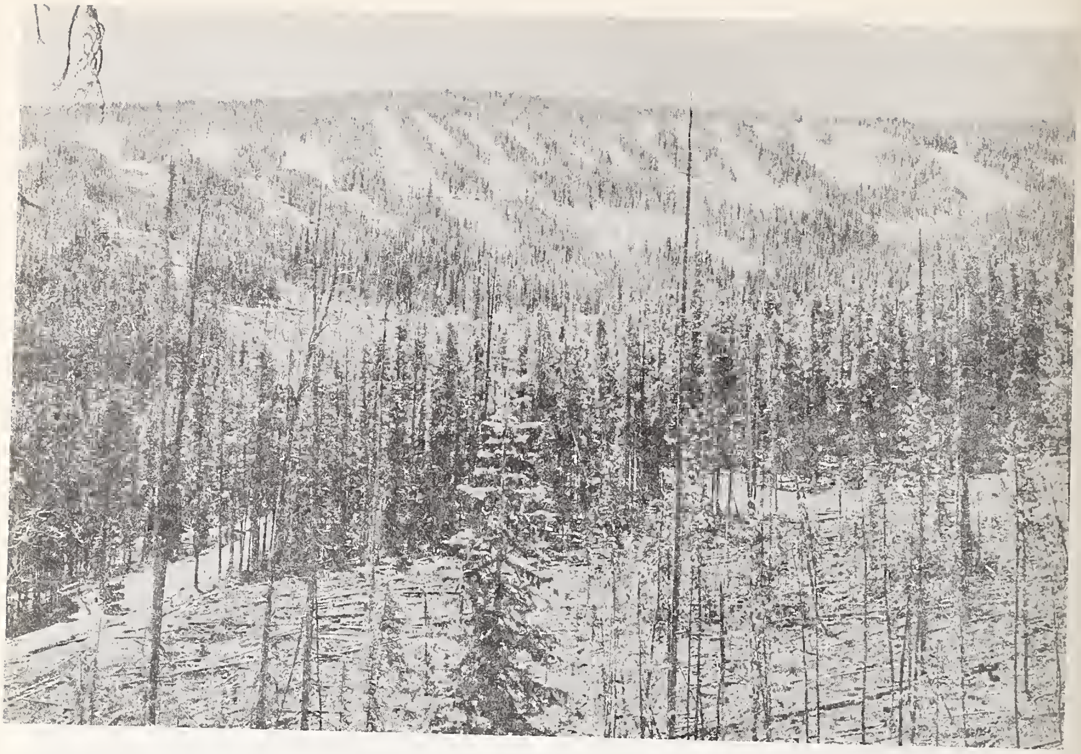

Figure 2. --Clear-cut strips in mid-June, Fool Creek watershed.

The total watershed area cleared was 278 acres. This figure includes 35 acres covered by the road system and 243 acres within the clear-cut strips. By class of product, and in thousands of board-feet (M b. m.), the volume of timber removed from the 243 acres was as follows:

Product	M b. m.	Percent
Sawlogs	2, 200	62
Poles	1, 000	28
Posts	60	2
Pulp	300	8
Total	3, 560	100

The study was not designed to determine the effect of timber harvest and its accompanying road system on sediment yield. Howeve to confirm the belief that erosion would not be a problem, a sediment basin was constructed in 1951 immediately below the stream-gaging station, and the volumes of deposited sediment have been measured annually since that time.

WATER-YIELD EFFECTS

The analysis to determine the effect of the treatment on water yield consists of estimating what the yield of Fool Creek would have been if there had been no treatment, and comparing this estimated value with that recorded. The estimation is made by means of a regression equation relating the water yield of Fool Creek to that of East St. Louis Creek for the years before the treatment of Fool Creek. The watershed of East St. Louis Creek has not been disturbed by timber harvest, and so remains as a "control" with its streamflow reflecting only the natural annual variations in climate.

The data from which analyses of water-yield changes were made are given in table 1. The years of record are grouped according to stages in the development of the watershed treatment. The presentation of the water yield in terms of area-inches eliminates from consideration the difference in size of the two watersheds by putting yield on a unit-area basis.

An initial analysis was made to reveal any effect of the Fool Creek road system on the water yield. For this analysis, only the years of 1943-50 were used to derive a pretreatment regression equation. However, no effect of the 35 acres of roadway clearing could be detected. Accordingly, for subsequent analyses data from the period 1943 to 1954, inclusive, were used to derive a regression equation. Although timber cutting began in 1954, the water yield during the spring and summer of that year was included with the pretreatment data because the timber cutting was not begun until July, and any change in soil moisture or winter snow accumulation would not influence water yield until the following spring.

Timber cutting was 80 percent complete at the end of the 1955 season and was completed in the fall of 1956. As shown by the following tabulation, streamflow was increased substantially in 1956. The greater increase in 1956 than for 1957 when cutting was completed is probably due to the difference in snowpack and melting conditions between the 2 years. Of course, more years of record are necessary before definite conclusions are possible.

Table 1.--Water yield from Fool Creek and East St. Louis Creek by treatment periods, yield for period of record

Year	Period of record	Fool Creek	East St. Louis Creek
		- - - Area-inches - - -	
	Before treatment		
1943	April 17 - September 28	12.66	15.19
1944	May 11 - " 26	8.01	12.19
1945	" 5 - " 26	10.54	16.09
1946	" 3 - " 26	9.73	11.88
1947	April 29 - " 25	14.67	19.15
1948	" 23 - " 22	10.92	14.73
1949	" 25 - October 3	11.67	17.52
1950	" 18 - November 5	10.67	15.74
Average		11.11	15.31
	Road building in progress		
1951	May 1 - October 6	14.28	17.95
	Roads completed		
1952	April 25 - October 5	16.05	20.41
1953	May 20 - September 29	10.07	14.23
1954	April 16 - October 17	4.66	7.79
Average		10.26	14.15
	Timber cutting in progress		
1955	April 30 - October 5	9.60	11.34
1956	May 3 - " 12	15.63	15.55
	After treatment		
1957	May 23 - September 30	23.01	25.31

	1956	1957
	(Area-inches)	
Predicted yield	11.4	19.6
Recorded yield	15.6	23.0
Increased yield	4.2	3.4
	(Acre-feet)	
Increased yield	250	200

SEASONAL DISTRIBUTION OF INCREASES

The effect of the treatment on the seasonal distribution of water yield is indicated by the hydrographs of figures 3, 4, and 5, in which comparisons are made between Fool Creek and East St. Louis Creek for the years before treatment and for each of the subsequent years. It can be seen that the bulk of increases in water yield take place during the spring freshet after timber harvest. However, streamflow has also been slightly higher during summer and fall in 1956 and 1957.

SPRING FRESHET PEAKS

Of particular interest in figures 4 and 5 is the difference between 1956 and 1957 in the relationships of the peak discharges of the two streams. In 1956, the peak rate of discharge by Fool Creek considerably exceeded that of East St. Louis Creek, while in 1957 it was relatively lower in magnitude. Statistical analyses bear out this observation. In 1956, the peak rate of discharge of Fool Creek was shown to be 50 percent greater than if there had been no watershed treatment; in 1957, the peak rate was 23 percent less than predicted.

June weather may account for the difference between 1956 and 1957. In 1957, a warm spell in mid-June caused early melting, especially on cutover areas of Fool Creek. Much of the snow melted on the lower part of the watershed (see fig. 2). A cool period followed that allowed drainage of stored ground water. The return of warm weather at the end of June caused further rapid snowmelt, but considerably less snow remained than on the uncut check area to feed the main peak. It thus appears that the effect of clearing depends on weather conditions and that the peak may be either increased or decreased by timber harvesting.

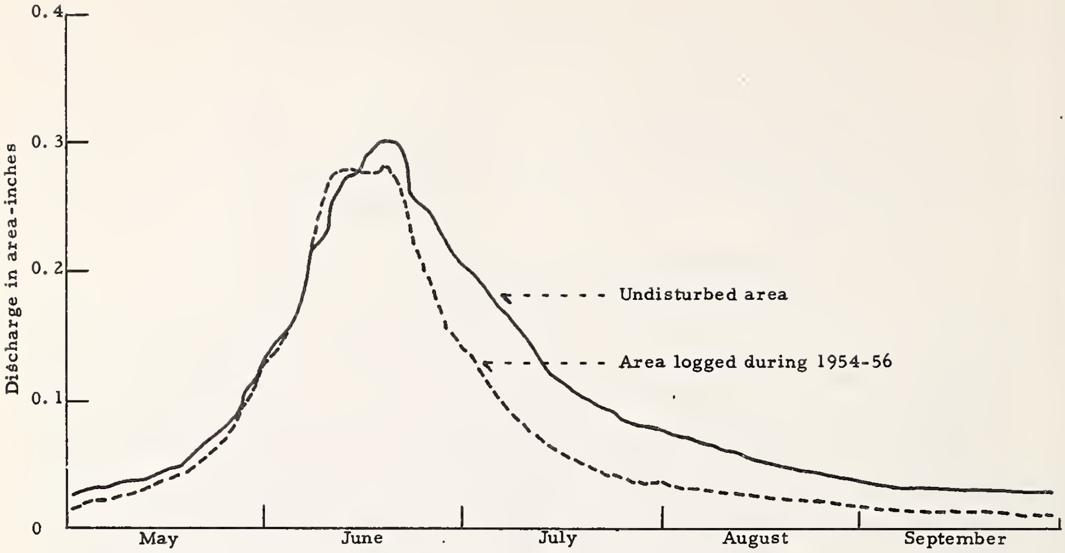

Figure 3. --Comparison of average stream discharge, 1943-54, before timber harvest on one of the watersheds, Fraser Experimental Forest.

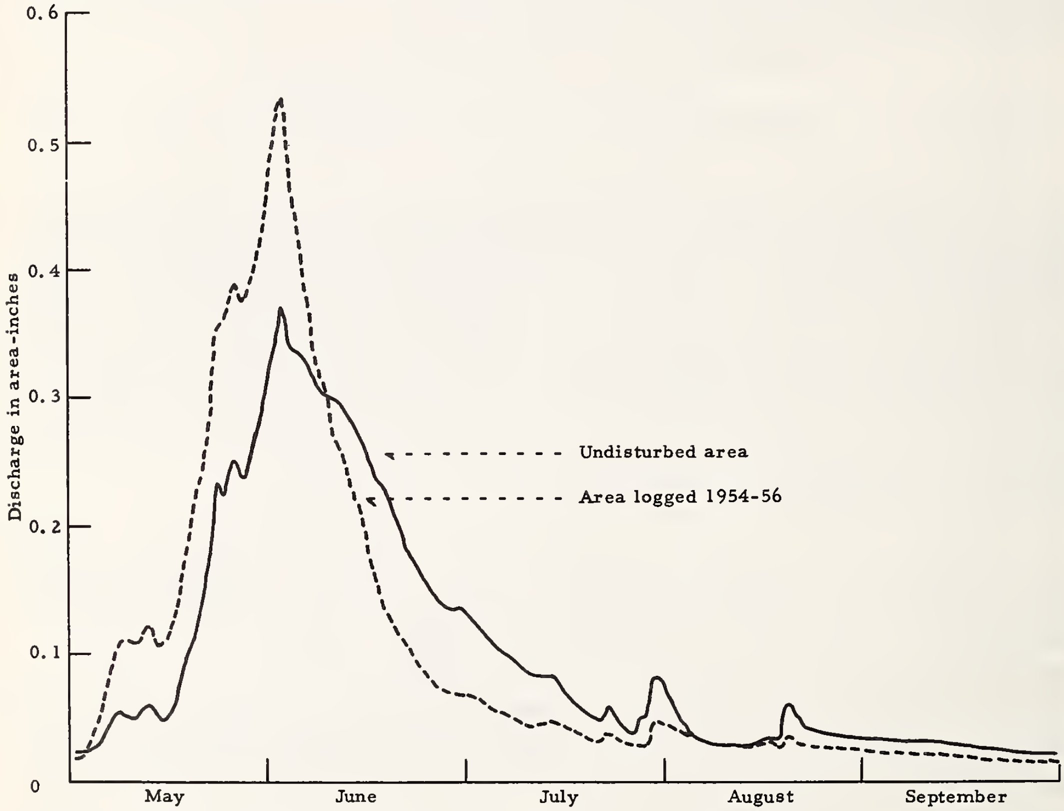

Figure 4. --Comparison of streamflow on paired watersheds for 1956 after timber harvest on one. Note the earlier rise in the hydrograph and higher peak rate. Fraser Experimental Forest.

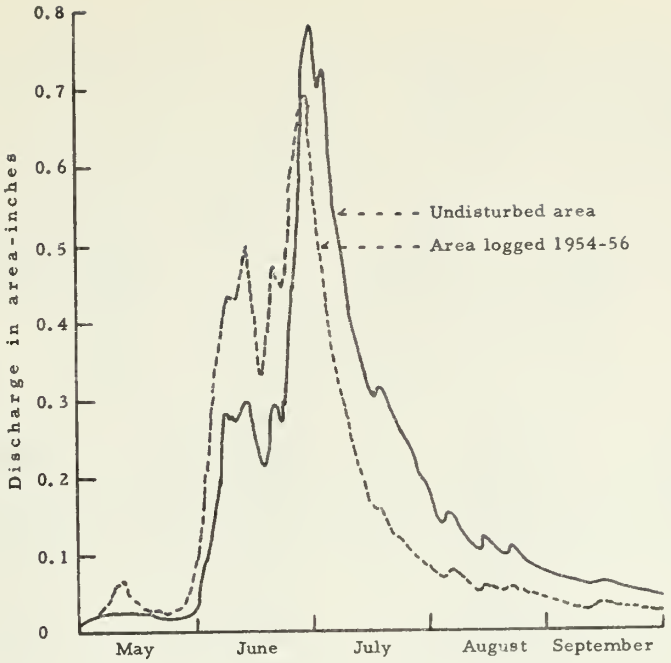

Figure 5. --Comparison of streamflow from paired watersheds in 1957. Note the earlier rise in the hydrograph, but lower peak rate. Fraser Experimental Forest.

The recorded data on annual peak discharges on both Fool Creek and East St. Louis Creek, together with the dates of occurrence, are given in table 2. Besides their pertinence to the study itself, these data are of interest for their revelation of the characteristics of such snow-fed mountain streams. The peak discharge rates are much less than is typical of rain-fed streams.

SEDIMENT YIELD

Because sediment measurements were begun after the road system was constructed, no conclusions can be drawn as to the effect of the watershed treatment on sediment yield. However, the sediment yield from such a watershed following logging is of interest and is shown in the following tabulation:

Table 2.--Date and instantaneous peak discharge by years

Year	Fool Creek		East St. Louis Creek	
	Date	Discharge	Date	Discharge
		Cu. ft./sq. mi.		Cu. ft./sq. mi.
		Before treatment		
1943	June 20	10.36	June 22	9.60
1944	June 15	8.67	June 19	10.07
1945	June 24	8.00	June 24	11.08
1946	June 10	11.34	June 6	10.26
1947	June 8	11.94	June 8	13.39
1948	June 3	11.79	June 3	11.12
1949	June 17	12.92	June 17	15.44
1950	June 16	15.44	June 16	15.31
		Road building in progress		
1951	June 20	17.72	June 21	15.31
		Roads completed		
1952	June 10	21.66	June 10	19.93
1953	June 13	14.04	June 13	15.44
1954	June 5	2.19	May 20	3.98
		Timber cutting in progress		
1955	June 8	6.10	June 8	5.94
1956	June 2	16.94	June 2	11.66
		After treatment		
1957	June 28	21.35	June 30	26.13

Year	Sediment yield from Fool Creek watershed (cu. ft. per sq. mi.)
1952	2.2
1953	1.1
1954	0.0
1955	0.0
1956	1.8
1957	3.4

Sediment yield is low and is correlated with discharge. Sediment was measured in place in the sediment basin and the tabulated volumes are wet volumes, including much leaf litter. The dry volumes of mineral matter would be appreciably less.

Visual observations have revealed that since the disturbance of the watershed the stream is visibly, but briefly, turbid during high spring stages and after the heavier summer rains. Before the watershed treatment, turbidity was never apparent. It is believed that this turbidity is caused by eroded material from roads.

SNOW ACCUMULATION BY STRIP WIDTH

Snow sampling in each of 2 years has revealed no effect of strip width on snow accumulation. Surveys were made on areas from which the timber was harvested in alternately cleared 1-chain strips and on areas where the strips were 6 chains wide. No differences in snowpack water equivalent were discovered.

SUMMARY

Appreciable increases in streamflow have followed the removal of one-half of the mature timber from the watershed of a snow-fed stream in the Colorado Rockies. The increase is estimated to be 250 acre-feet in 1956, and 200 acre-feet in 1957. Merchantable timber covered 550 acres of the 714-acre watershed. The area actually cleared of timber was 278 acres, and was cut in strips 1, 2, 3, and 6 chains wide which alternate with equal-width uncut strips. The spring flood peak was increased the first year after cutting and decreased in comparison with the control in the second year. The interaction between spring weather and treatment seems to explain the difference in spring peaks. Sediment yields since the cutting have been low. Snow accumulation was increased on the cut strips and the increase appears about the same for each of the widths of strip used and tested in this study.

The indicated changes in water yield and peak flows cannot be used to estimate what the long-term effect of the watershed treatment will be. Several more years of observation are required to learn the interaction between the effects of cutting and climatic factors.

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